Strategy for A Restructured U.S. Fusion Energy Research Program

Introduction

The Department of Energy's mission includes the development of fusion as one of the few long-term energy options with virtually unlimited fuel supply and favorable potential as a safe and environmentally attractive energy source. Under the reduced Federal funding envisioned for fusion, the U.S. Fusion Energy Program is being restructured to focus on fusion's underlying scientific foundations, including those technologies needed to enable scientific discoveries, and on fostering improvements in plasma confinement concepts in order to reduce the size and cost of future fusion power plants. Such a focus will also substantially strengthen the field of plasma science - a field in which the U.S. is the world leader and which has developed a variety of techniques widely applicable to other areas of science and technology. This revised strategy which focuses on the underlying science is a substantial departure from the Program's previous schedule-driven strategy aimed at operation of a demonstration power plant by the year 2025.

To accommodate reduced budgets for the foreseeable future, the Program must cut deeply into its considerable investments in human resources and facilities. In pursuing its new strategy, the Program will rely heavily on existing facilities, and will use the leverage offered by international linkages to contribute to and capitalize on the world fusion effort. Continued emphasis on innovation and the intellectual challenge of fusion will nurture the vitality and scientific richness needed to retain and attract the scientists and engineers required to accomplish this task.

Program Mission

Establish the scientific and technological foundations for an economically and environmentally attractive fusion energy source.

Core Values

The extraordinary challenge of fusion requires major advances in our knowledge of plasma physics, fusion technology and materials science. The development of the underlying fusion science and enabling technology, the foundation for such advances, is the single most

DRAFT

important program element. A few examples among many topics requiring progress in understanding are plasma-wall interactions, plasma stability and transport, high-heat-flux alloys, and alpha-particle relaxation. Fusion research of the required quality depends upon: (i) the maintenance of a broad, vigorous talent pool, working in an intellectual environment that encourages creativity and innovation; (ii) effective connections to related scientific and engineering disciplines; (iii) a range of experimental facilities, including small devices for exploratory studies as well as larger facilities capable of approaching the physical conditions of a fusion reactor; and (iv) effective leverage of U.S. efforts through mutually beneficial international linkages.

Strategy

The issues of confinement concept optimization, burning plasma physics, and low activation materials remain fundamental to fusion research; they must be addressed by the restructured Program. The restructured Program will place a greater emphasis on concept optimization and a lesser emphasis on burning plasma physics, building on the significant accomplishments and valuable resources of the scientific program. Efforts on low activation materials will remain at a modest level compared to the other two. The issue of fusion power technology, including blankets and tritium handling, is also fundamental and must be addressed in the future as part of a fusion energy development program; this issue will not be addressed by the restructured Program except for small-scale efforts in selected key areas.

The three fundamental issues, associated objectives, and the approaches to addressing these issues in the restructured Program are discussed below. The objectives, while bold and challenging, can be pursued at a lower level of resources than was required for achieving the more ambitious goals of the previous Program strategy.

- <u>Confinement Concept Optimization</u>: Establish the scientific basis for one or more promising plasma confinement approaches that could lead to a significantly simpler, less expensive, and more reliable fusion energy source than one based on the present data base.

DRAFT

Recent advances in understanding and performance that have been made with both tokamak and alternate plasma confinement approaches have illustrated the potential for major improvements in the attractiveness of fusion energy sources. The realization of this potential requires a broad-based fusion science and enabling technology program that fosters innovation and creativity. A two-pronged approach will be pursued: research to enhance the performance and attractiveness of tokamaks, conducted primarily through reliance on existing facilities, and expansion of the exploration of promising alternate plasma confinement approaches. Where appropriate, program activities will take into account the substantial fusion research investments being made and the innovative work being undertaken on alternate confinement approaches in

Europe, Japan, and Russia. In addition, inertial confinement fusion is being pursued in the Department's Defense Programs, with a relatively small research effort on energy-specific enabling technology in the Fusion Energy Research Program.

- Physics of Burning Plasmas: Establish the scientific basis needed to understand and predict the behavior of burning plasmas under conditions relevant to a fusion energy source.

Exploring the many physics aspects of optimizing and sustaining burning Deuterium and Tritium (i.e., D-T) plasmas has been a major objective of the Program. In the near term, it is possible to address this objective experimentally for short pulses and moderate levels of alpha particle production in existing D-T devices. Important physics issues will also be addressed in the near-term by theory and by devices operating with plasmas that, while not D-T, simulate some of the phenomena in burning

DRAFT

D-T plasmas. Given the constrained budget outlook for the Program, exploration of the physics of burning plasmas for long pulses and substantial alpha particle production can only be met through collaboration in broader international activities. As part of this, the Program will continue to participate in the International Thermonuclear Experimental Reactor (ITER) Engineering Design Activities (EDA). The Program will also seek to participate, even at a modest financial level, in the construction and operation of an international D-T plasma burning device as now embodied in ITER, in order to explore more thoroughly the physics of burning plasmas at high energy gain.

- Low Activation Materials for Fusion: Establish the feasibility of using low activation materials to significantly enhance fusion's potential as a safe and environmentally attractive energy source.

The materials surrounding a burning plasma must function in a demanding environment which includes high heat fluxes, substantial mechanical loads, and intense neutron bombardment. Development of compatible first-wall and blanket materials with low-activation characteristics is essential if fusion is to realize its full potential as a safe, economical, and environmentally attractive energy source. Because development of materials for the fusion environment requires a basic understanding of materials behavior under a combination of severe operating conditions, this is recognized as a long-term undertaking. This objective will be accomplished through strong international collaboration on materials development based on fundamental research. It is expected to include a modest level of participation in an international materials testing facility to gain knowledge about the performance of materials in a characteristic fusion neutron environment.

DRAFT

Conclusion

In this revised program strategy, the focus of the U.S. fusion program has shifted from the operation of a demonstration power plant in 2025 to fostering improvements in confinement concepts and the underlying science and enabling technology of fusion. Human resources exist within the Program to support the new strategy and to contribute toward the world's fusion effort in many areas of critical need. The Program will require a range of national experimental facilities, from existing and new devices for exploratory studies, to larger facilities that can approach the operating conditions of a fusion energy source. Existing experimental facilities can address many of the Program objectives and provide information required for successful completion of the ITER EDA. The Program will continue to be an effective participant in the ITER EDA and will attempt to participate, even at a modest financial level, in the construction and operation of an international D-T plasma burning device as now embodied in ITER. Continued development of enabling technologies, support for theory and computational efforts, system studies, and use of international collaboration will permit the restructured Program to realize its vision.